Site and Reach Assessment
SR 530 Sauk-Suiattle Confluence at MP 55.5
Chronic Environmental Deficiency Site

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Table of Contents

Figures

Tables

Introduction and Summary

The Washington State Department of Transportation (WSDOT) established the Chronic Environmental Deficiency (CED) program to provide for highway improvements at locations where repeated maintenance activities create unacceptable environmental impacts. WSDOT prioritizes CED sites using an environmental retrofit index that gives special weight to protection of fish habitat.

This report presents a site and reach assessment for a CED site at the confluence of the Sauk and Suiattle Rivers at SR 530 Milepost (MP) 55.5 near Darrington, WA (Figure 1). Changes in the configuration of the confluence have caused the Sauk River to erode into the SR 530 embankment along about 1300 feet of the left bank. A series of groins were installed at this site in 2008 based on recommendations from an earlier emergency reach assessment (WSDOT, 2007). These have slowed but not halted the erosion problem.

The report evaluates alternatives for long-term stabilization of the eroding bank. These alternatives are described at a conceptual level to allow project stakeholders to identify a preferred alternative for scoping, funding, and more detailed design. The report builds on and updates the findings contained in the 2007 emergency reach assessment. It also references information described in annual geomorphic monitoring reports prepared after construction of the groins (WSDOT, 2009, 2010, and 2011).

Existing armor and deflection structures are adequately protecting the bank between Groins 1 and 9, but toe erosion has undermined the bank between Groins 10 and 11. The unarmored segment between Groins 9 and 10 is also at risk because these groins are spaced too far apart. The erosion between groins 10 and 11 was initiated in the winter of 2009, and continued through 2011. Banklines measured in December 2012 and August 2014 show no significant additional erosion since April 2011.

The erosion is occurring at the edge of the channel migration zone where the river is cutting into a glacial terrace. Sediment bars at the site shift and grow dynamically in response to high sediment loads from the Suiattle River. This changes the angle of attack against the bank and increases erosive forces.

We identified four alternative bank treatments that could address the mechanisms and causes of failure and stabilize the segments of bank between Groins 9 and 11 that are at highest risk:

1. Construct two additional rock and wood groins; lengthen groins 9 and 10.
2. Construct a roughened log and rock toe.
3. Construct a riparian bench reinforced with a log cribwall.
4. Construct a riparian bench reinforced with dolo-anchored log clusters.

Table 2 compares the costs, impacts, and benefits of these alternatives. We recommend Alternative 1 (additional groins) because this would have the lowest cost and least impact on riparian and aquatic habitat. The bank between Groins 10 and 11 should also be reinforced with a log and rock toe because it has failed close to the point where erosion can undermine the road prism.

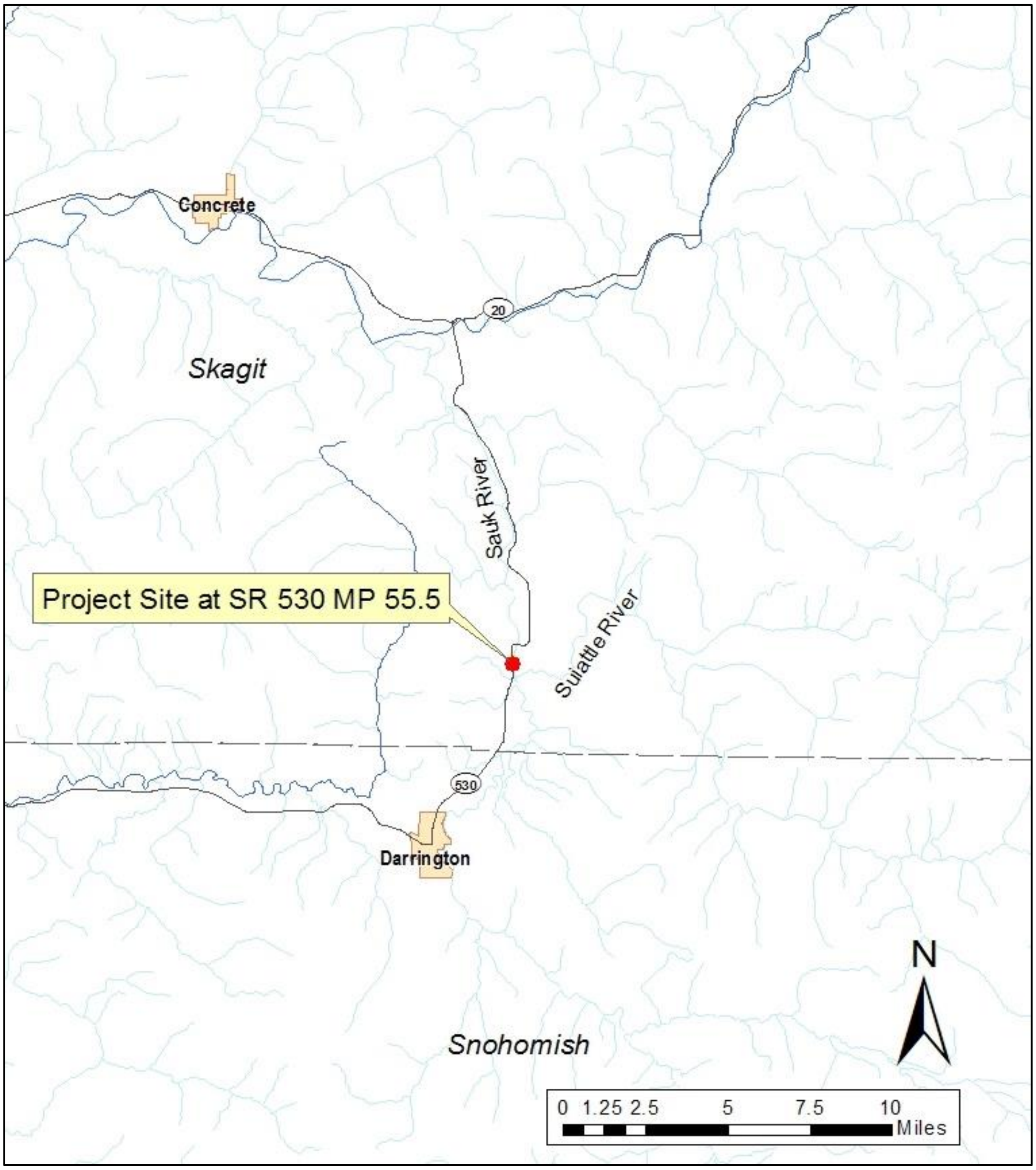

Figure 1. Location of the Sauk-Suiattle Confluence CED site.

Site Assessment and Repair History

The project site extends from the Sauk-Suiattle confluence to a point about 1700 feet downstream. Up until November 2006 this road segment was separated from the river by 50 to 60 feet of forested terrace that was 12 to 15 feet above the river. The bank did not require maintenance in the decade prior to 2006.

The record November 2006 flood drastically changed the configuration of the confluence, shifting the Sauk River against the left bank along SR 530. This flood eroded the toe of the bank and created tension fissures that caused slabs of bank material and vegetation to calve off into the river. The top of the eroded bank advanced to within 20 feet of the edge of the highway.

WSDOT determined that this erosion posed a severe and imminent threat to SR 530, and in 2008 constructed twelve groins buried in the bank (Figure 2a). The groins were made up of angular rock and approximately 90 pieces of embedded large woody material (LWM). The design was developed to ensure prompt regulatory approval that would enable construction prior to high flows in the river. WSDOT understood that the length of some of the groins and the distance between them could result in erosion between the groins that would extend into a portion of the road prism. However, there was a potential for catastrophic loss of the entire road prism had WSDOT not taken action, and this was determined to outweigh the risk.

Groins 1 and 2 are located just upstream of the confluence and have not yet been exposed by erosion. High flows in the winter after construction exposed six of the shortest groins (Groins 3 to 8) and eroded between them to the edge of the road prism. These groins were subsequently extended to increase protection of areas between the groins. Eroded areas between the groins were reinforced with rock and LWM. A total of 66 additional pieces of LWM were incorporated into the project at this time. Geomorphic monitoring reports in 2010 and 2011 observed sand deposition, wood recruitment, and stable banks between most of these repaired groins. The area between Groins 7 and 8 did not receive new wood placements and therefore experienced additional bank erosion and failure of rock riprap.

Aerial photos from September 2009 show the onset of new erosion near Groin 10 at the downstream end of the repair site. By April 2011 this erosion had progressed to within 20 feet of the road shoulder and was occurring in most of the bank between Groins 10 and 11. The 2011 Geomorphic Monitoring Report concluded that Groins 9-11 were spaced too far apart to effectively protect the bank, and recommended adding two new groins (WSDOT, 2011). The report also recommended extending Groins 9 and 10 and adding rock armor and LWM to the toe of the bank between Groins 10 and 11, similar to repairs previously done for upstream groins. These recommendations have not yet been implemented.

We observed no major changes in the condition of the bank during site visits in December 2012 and August 2014, aside from some undermining of riparian vegetation downstream of Groin 8. Figures 2a and 2b compare GPS bankline measurements from 2011, 2012, and 2014. No major floods occurred in this period.

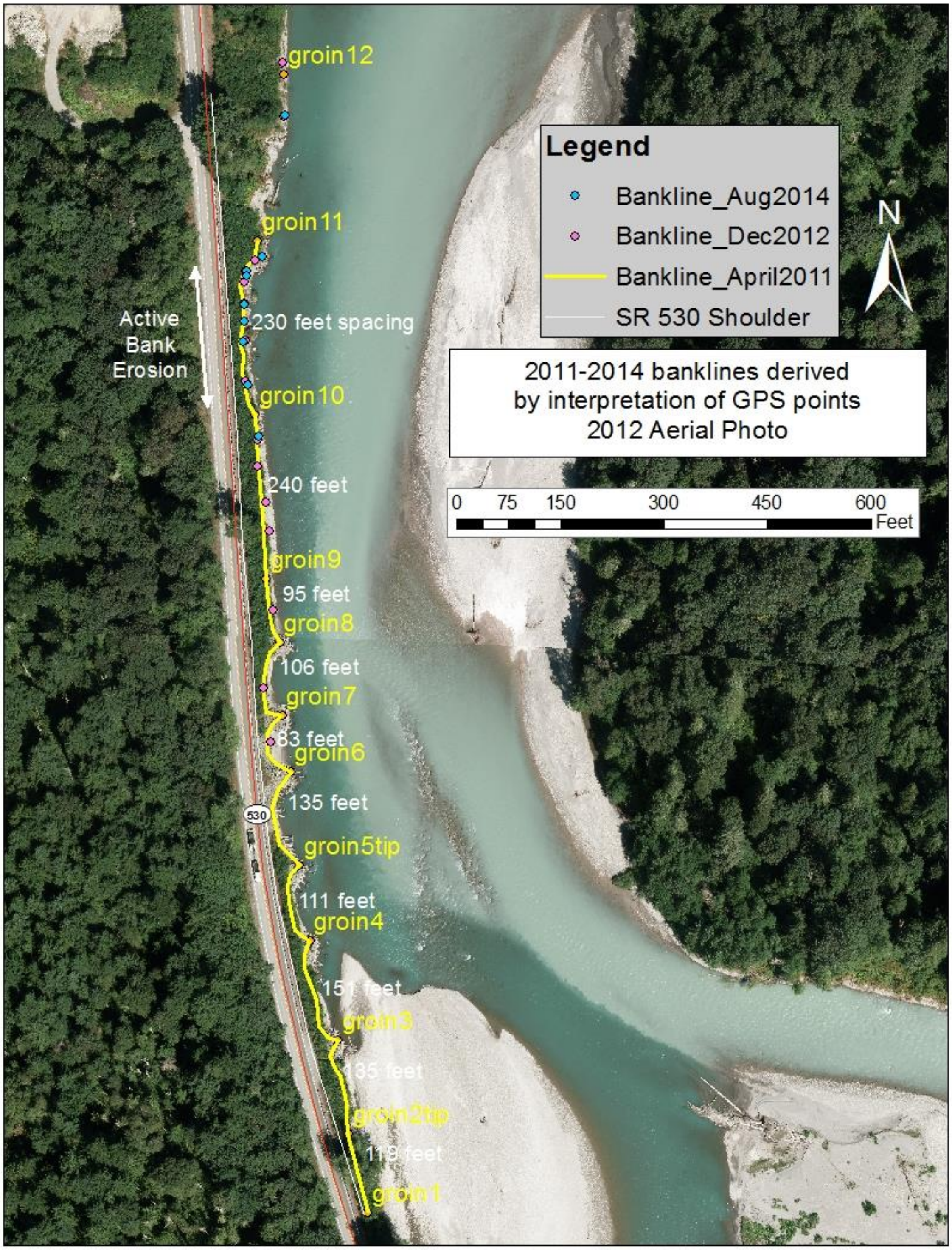

Figure 2a. Locations of groins and banklines in April 2011, December 2012, and August 2014.

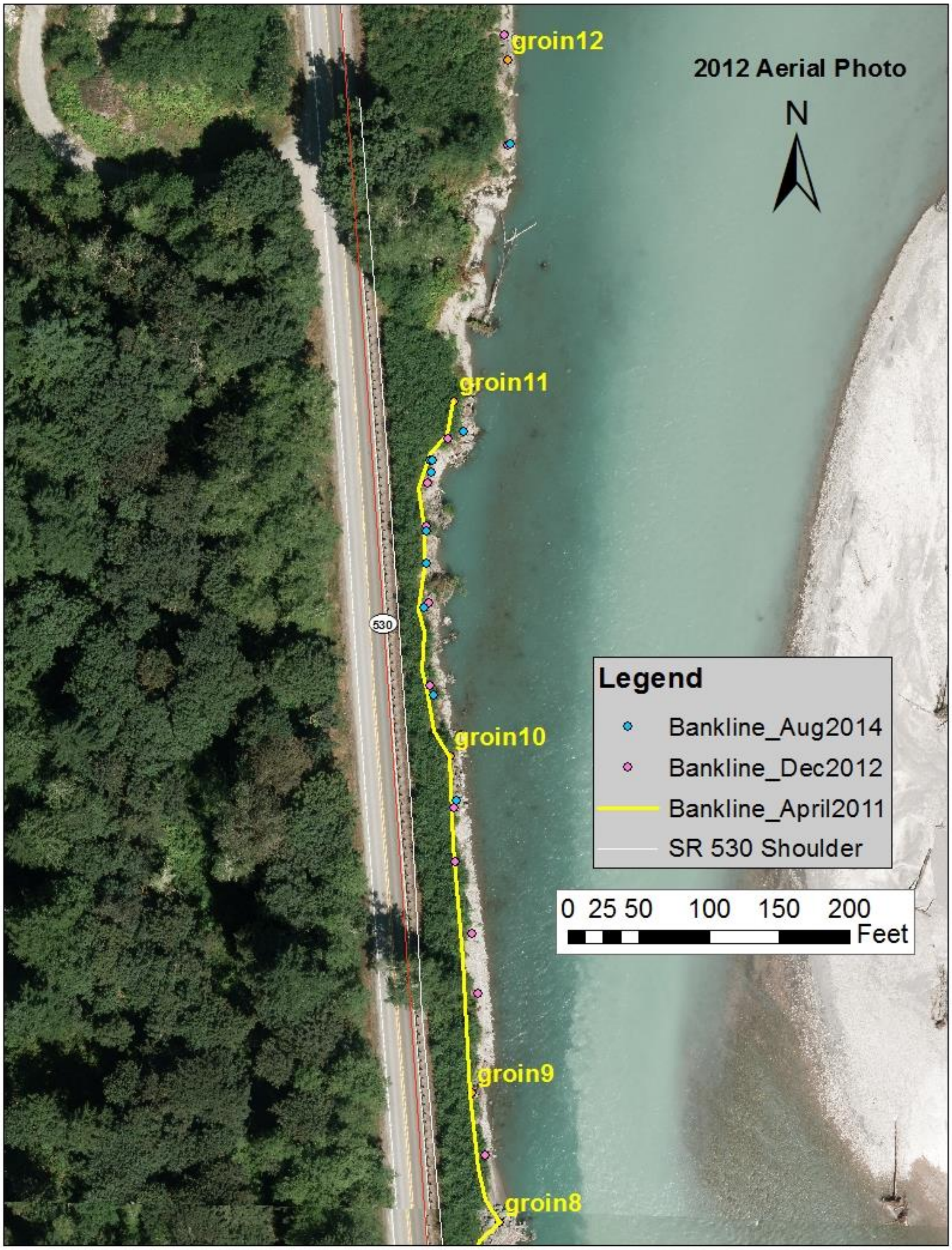

Figure 2b. April 2011, December 2012, and August 2014 bank measurements between Groins 8 and 12.

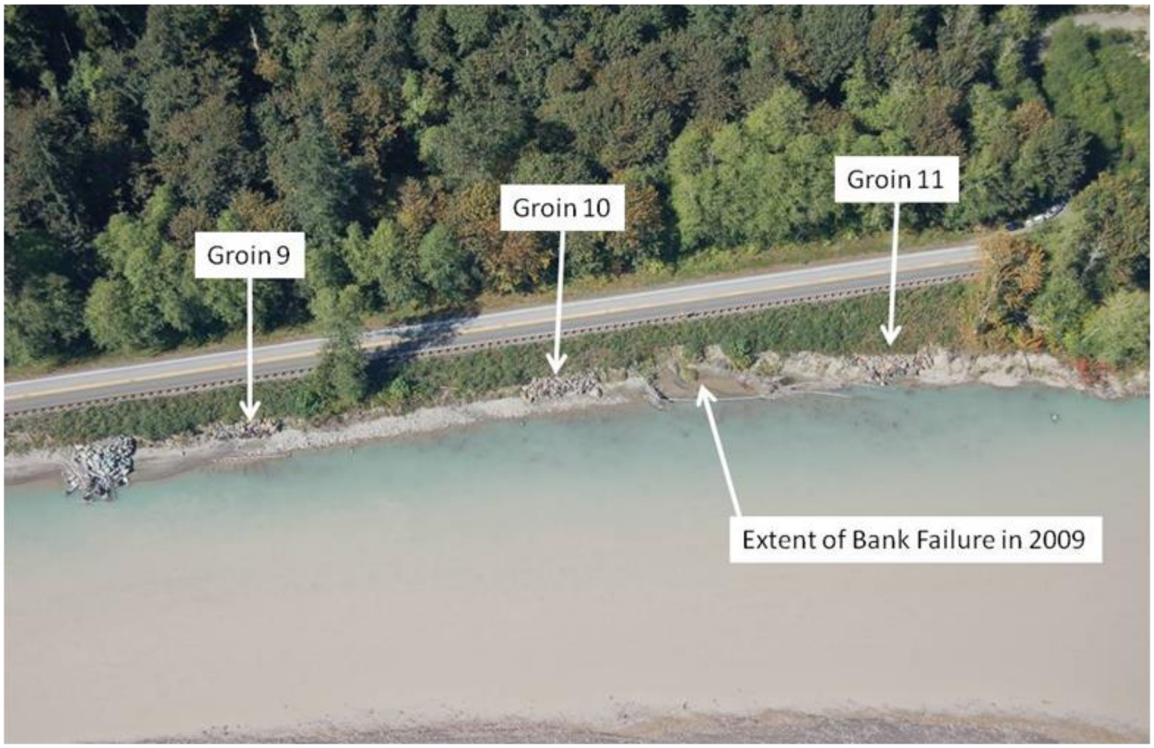

Figure 3. Initiation of bank failure near Groin 10, September 2009 aerial photo.

Reach Assessment

This reach assessment summarizes findings from the emergency reach assessment report (WSDOT, 2007), and provides updates as necessary to reflect current conditions.

Watershed Conditions and Hydrologic Trends

The steep and mountainous headwaters of the Sauk basin receive heavy rainfall and develop an extensive winter snow pack. Tributaries are fed by glaciers on the west slope of Glacier Peak. Forest covers most of the watershed. Residential development is concentrated in and around the town of Darrington.

Table 1 summarizes flood frequency statistics estimated for the project area using flow data through 2011, and compares these to more recent peak flows (USGS, 2007 and 2014). Floods are usually generated by heavy rainfall and rain-on-snow events in November and December. The October 2003 and November 2006 floods are the most significant channel-forming events in the last decade. Peak flows for the water years since 2007 have had recurrence intervals ranging from one to four years. Climate and flow data in the region show a trend towards more extreme and frequent floods generated by warmer winter storms and less storage in glaciers on Glacier Peak.

Geomorphic Conditions

The active floodplain of the Sauk River is covered by deep and highly permeable soils that form in sandy alluvium (USDA, 1981). The Suiattle River deposits a large delta of coarse alluvium at the confluence. Older terraces of glacial outwash and lahar deposits line the floodplain alluvium on both sides of the valley. These terraces lie above the active floodplain, and are only subject to erosion when the river's channel migration zone widens beyond its historical pattern. The river at the project site has recently eroded through alluvial deposits on the left bank to cut into a glacial terrace that underlies SR 530. A high rock bluff sits about 80 feet west of the road and forms the western boundary of the terrace.

WSDOT drilled seven bore holes to depths of about 27 feet along the riverbank at the 2008 repair site. These encountered 8 to 20 feet of loose silty sand underlain by dense silty sand with gravel and silty gravel. A very dense layer of sand with gravel or silty gravel was encountered at 12 to 24 feet depth. Bedrock was not encountered in any of the holes.

Sediment transport and deposition in the project reach are heavily influenced by the Suiattle River. The Sauk River flows at an average gradient of about 0.3 percent upstream and downstream of the Suiattle confluence. The Suiattle approaches the confluence at a steeper slope of 0.5 percent, and delivers a large load of sediment into the slower-moving Sauk. Sediment deposition at the mouth causes the Suiattle confluence to shift between several alternative channels. This leads to frequent changes in the Sauk's flow path and angle of attack on the left bank adjacent to SR 530.

Table 1: Peak flood flow statistics and recent annual peak flows.

Event	**Peak Flow (cfs), Sauk River near Sauk USGS Gage 12189500** *Drainage Area 714 mi²*
2-year	31,630
10-year	61,970
25-year	79,800
50-year	94,150
100-year	109,400
Oct. 20-21, 2003 (Highest, 85 year event)	106,000
Nov. 6, 2006 (3rd Highest, 30 year event)	86,400
Dec. 04, 2007 (4 year event)	45,700
Nov. 12, 2008 (3 year event	41,700
Nov. 17, 2009 (2 year event)	29,500
Dec. 12, 2010 (3.5 year event)	44,600
Nov. 23, 2011 (1.3 year event)	21,100
Sep. 29, 2013 (1.3 year event)	20,800
Mar. 9, 2014 (1.4 year event)	22,900

Historical Channel Migration

Historical aerial photos illustrate the dynamic nature of the confluence. In 1964 the Suiattle split between the current confluence and a larger channel located about 2300 feet to the south of the project site (Figure 4). SR 530 at the project site was separated from the river at this time by more than 100 feet of riparian forest. The southern channel was abandoned sometime between 1974 and 1992, and all of the Suiattle's flow is now concentrated in a braided channel that enters the Sauk just opposite of the project site (Figure 5). This has caused the river to steadily erode into the riparian terrace that once buffered the highway from the river.

Figure 5 shows recent changes in the configuration of the confluence that have increased the erosion problem. After the November 2006 flood the Suiattle shifted northward to enter the Sauk at a near perpendicular angle of attack directly opposite the upstream end of the site. This increased flow curvature and shear stresses against the upstream end of the site where erosion problems were concentrated prior to the 2008 repair. The 2006 flood also brought sediment into the system that led to steady growth of a sediment bar opposite the site, narrowing the channel and bringing more energy against the left bank.

Between 2009 and 2011 flow patterns shifted to bring more erosive energy against the downstream end of the site (near groins 9, 10, and 11). A new sediment bar built up on the left bank just upstream of the site, pushing the Sauk into an S-curve through the confluence. As it merges with the Suiattle the Sauk then bends sharply against the downstream end of the site. The right bank bar has also continued to grow downstream of the confluence, especially opposite groin 10.

Photos from 2012 and 2013 show only minor changes in channel configurations since 2011. No major flood events occurred during this period (Table 1).

Riparian Conditions and Large Woody Debris

Riparian forests in the Sauk valley reflect regular disturbance typically found in geomorphically active floodplains. Stands are dominated by alder of various ages, with younger trees occurring near the apex of point bars and along the margins of relic channels, and older trees found on islands and along portions of the floodplain not recently accessed by the river. A substantial portion of the floodplain has been denuded by recent large flow events. WSDOT has replanted most of the area stabilized by the SR 530 repair with a dense thicket of riparian trees and shrubs, but these have not yet matured to a point where they are providing woody debris or shade to the system.

The upper Sauk and Suiattle basins contain mature riparian forests that deliver large woody debris to the system. Riparian forests near the project site are less mature and have lower potential for large woody debris recruitment. The Sauk River has high flow energy that mobilizes woody debris during floods, so most wood is deposited either on the upper sediment bars or at obstructions such as the groins used to stabilize SR 530. Geomorphic monitoring reports have observed significant woody debris recruitment on and between the SR 530 groins.

Fish Utilization and Habitat Availability

The project reach is utilized by spring and summer Chinook, fall chum, coho, pink, and sockeye salmon, winter and summer steelhead, cutthroat, and bull trout. These species are known to either rear or spawn in the project reach. Chinook, steelhead, and bull trout are listed as threatened in the region under the Endangered Species Act.

The Limiting Factors Analysis for the upper Skagit basin identified the following priorities for improving salmon habitat in the mainstem Sauk (Washington State Conservation Commission, 2003):

- Preserve functioning floodplain habitat, such as edge habitat, wetted off-channel habitat, and connected functional riparian forests.
- Reconnect and restore riverine wetland habitat along mainstem and larger tributaries.
- Decommission or treat road segments that are at a high risk of delivering sediment to streams.
- Restore degraded riparian conditions throughout the Skagit Basin.

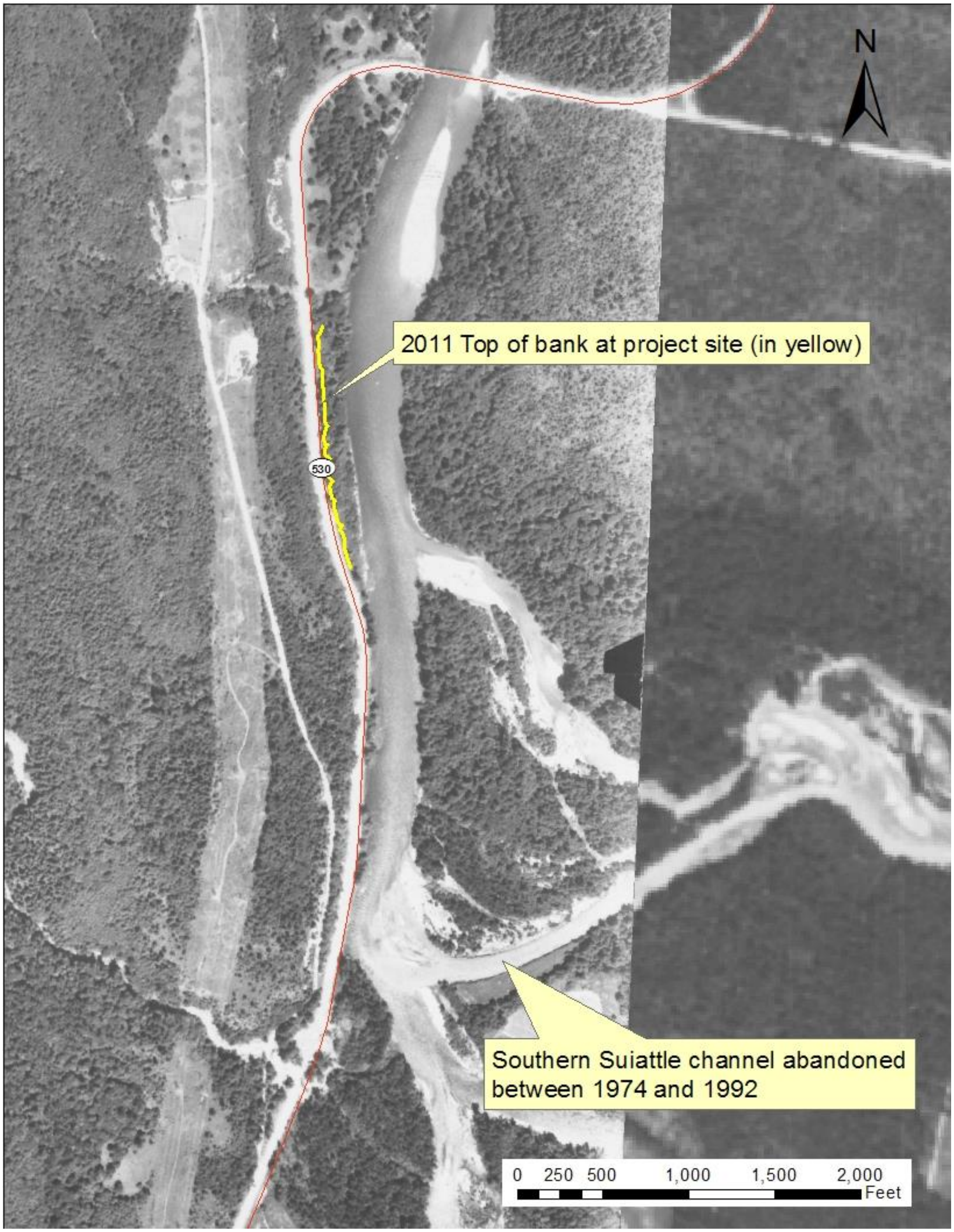

Figure 4. Configuration of the Sauk-Suiattle confluence in 1964.

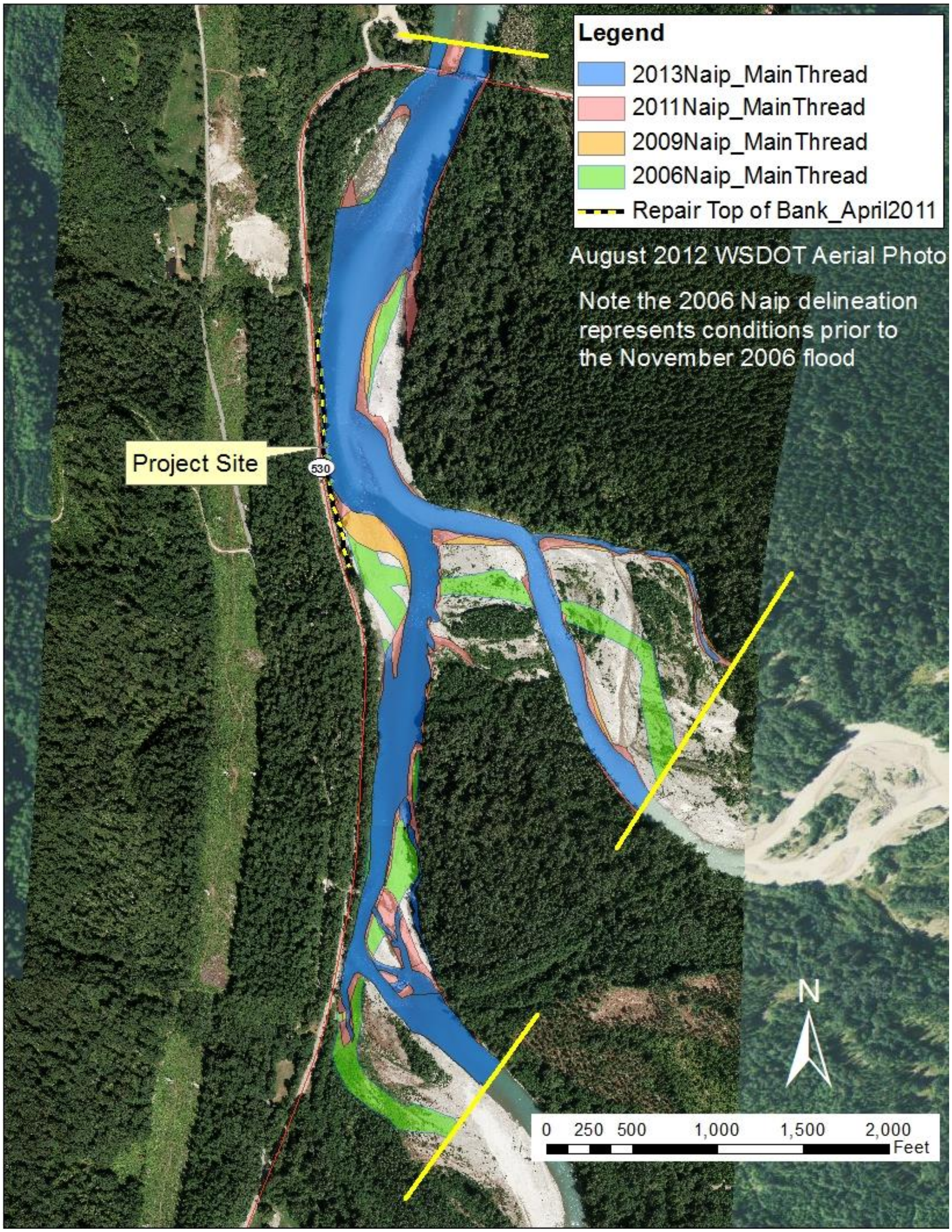

Figure 5. Channel patterns shown in aerial photos from 2006-2013.

Treatment Alternatives

Project Objectives

The objectives of the project will be to:

- Reduce maintenance costs and habitat impacts by addressing site- and reach-scale mechanisms and causes.
- Avoid increases in flooding and erosion risks to adjacent properties.
- Minimize in-water construction impacts to water quality, sediment, and fish.
- Minimize long-term habitat impacts that would require off-site mitigation.

Screening to Identify Alternatives based on Mechanisms and Causes of Failure

Existing armor and deflection structures are adequately protecting the bank between Groins 1 and 9, but changes in the confluence have increased flow curvature and directed erosive energy at about 200 feet of unarmored bank between Groins 10 and 11. This has initiated toe erosion and failure of slabs of root masses, creating a vertical scarp of bare bank material. Another 200 feet of bank between Groins 9 and 10 is also at risk because the groins are spaced too far apart. Selection matrices in the Integrated Streambank Protection Guidelines (ISPG) identify the following treatments as suitable for these site-based mechanisms where infrastructure is threatened and space is limited (WDFW, 2003):

- Deflection structures (groins, engineered log jams configured as groins, or barbs).
- Riprap.
- Roughened log and rock toes.
- Log cribwalls.

The erosion is occurring at the edge of the channel migration zone where the river is cutting into a glacial terrace. Sediment bars on both sides of the river can shift and grow dynamically in response to changes in the configuration of the Suiattle confluence. Most of the above treatments can work for these reach conditions, but deflection structures will need to be carefully designed to ensure they will work for the range of river flow patterns that may occur in this dynamic confluence area. Rock riprap treatments can be used as part of armoring systems but will need to incorporate wood to meet project objectives for avoiding off-site mitigation.

Based on the screening analysis we selected the treatment alternatives shown in Table 2 for further consideration to protect the segments of bank at highest risk between Groins 9 and 11. These are described in more detail below.

Table 2: Comparison of treatment alternatives.

Alternative	Costs	Construction Impacts and Risks	Long Term Impacts	Habitat Benefits
1a. Additional groins constructed of rock and wood	Moderate	Turbidity control needed for log and rock placement. Damage to existing riparian habitat for access and excavation.	Loss of aquatic bed habitat under the groin footprint. Some risk of bank failure between groins.	Creation of eddy and pool habitat between and around structures. Roughness and velocity reduction. Cover habitat from projecting rootwads.
1b. Additional groins constructed as logjams	High	Extensive dewatering and turbidity control. Damage to existing riparian habitat for access and excavation. Pile driving impacts to endangered fish and other species. Geotechnical investigation needed to determine feasibility of pile driving.	Larger footprint and more fill on the aquatic bed than for rock groins. Some risk of bank failure between groins.	Creation of eddy and pool habitat between, within, and around structures. Extensive roughness and velocity reduction. Extensive cover habitat around entire structure. Opportunities for riparian planting on top of structures
2. Roughened log and rock toe	Low-Moderate	Turbidity control needed for log and rock placement. Extensive damage to existing riparian habitat for access and material placement.	Loss of aquatic habitat under the rock footprint. Higher likelihood of failure and future maintenance if used without other treatments that deflect and reduce velocities.	Roughness and cover provided by logs at toe.

3. Riparian bench reinforced with a log crib-wall	Very High	Extensive damage to existing riparian habitat for access and excavation. Pile driving impacts to endangered fish and other species. Geotechnical investigation needed to determine feasibility of pile driving.	Loss of aquatic habitat under the treatment footprint.	Restoration of a much broader and robust riparian zone. Cover habitat and roughness along face of the crib-wall. Highly effective treatment with low risk of future maintenance.
4. Riparian bench reinforced with dolo-anchored log clusters	Very High	Extensive damage to existing riparian habitat for access and excavation. Structures may be more difficult to permit due to aesthetic concerns and perceived habitat loss associated with concrete dolos.	Greater loss of aquatic habitat under the structure footprint than for other treatments.	Restoration of a much broader and robust riparian zone. Cover habitat and roughness along face of the treatment. Highly effective treatment with low risk of future maintenance.

Alternative 1 – Additional Groins Constructed of Rock and Wood

This alternative lengthens existing Groins 9 and 10 and adds two new partially buried groins as recommended in the 2011 monitoring report (Figure 6). A groin can generally protect a length of bank equal to 3.3 times its projected length perpendicular to the bank. Four groins in this area would each need to protect 118 feet of bank (measured from the centers of the groins), and therefore would need to be at least 36 feet long. The following groin modifications would therefore be needed to protect a minimum 20 foot riparian buffer from the road shoulder (rounding the required groin lengths up to account for uncertainty):

- Lengthen Groins 9 and 10 by 25 feet.
- Install a new partially buried 40-foot groin between 9 and 10.
- Install a new 40-foot groin between 10 and 11.

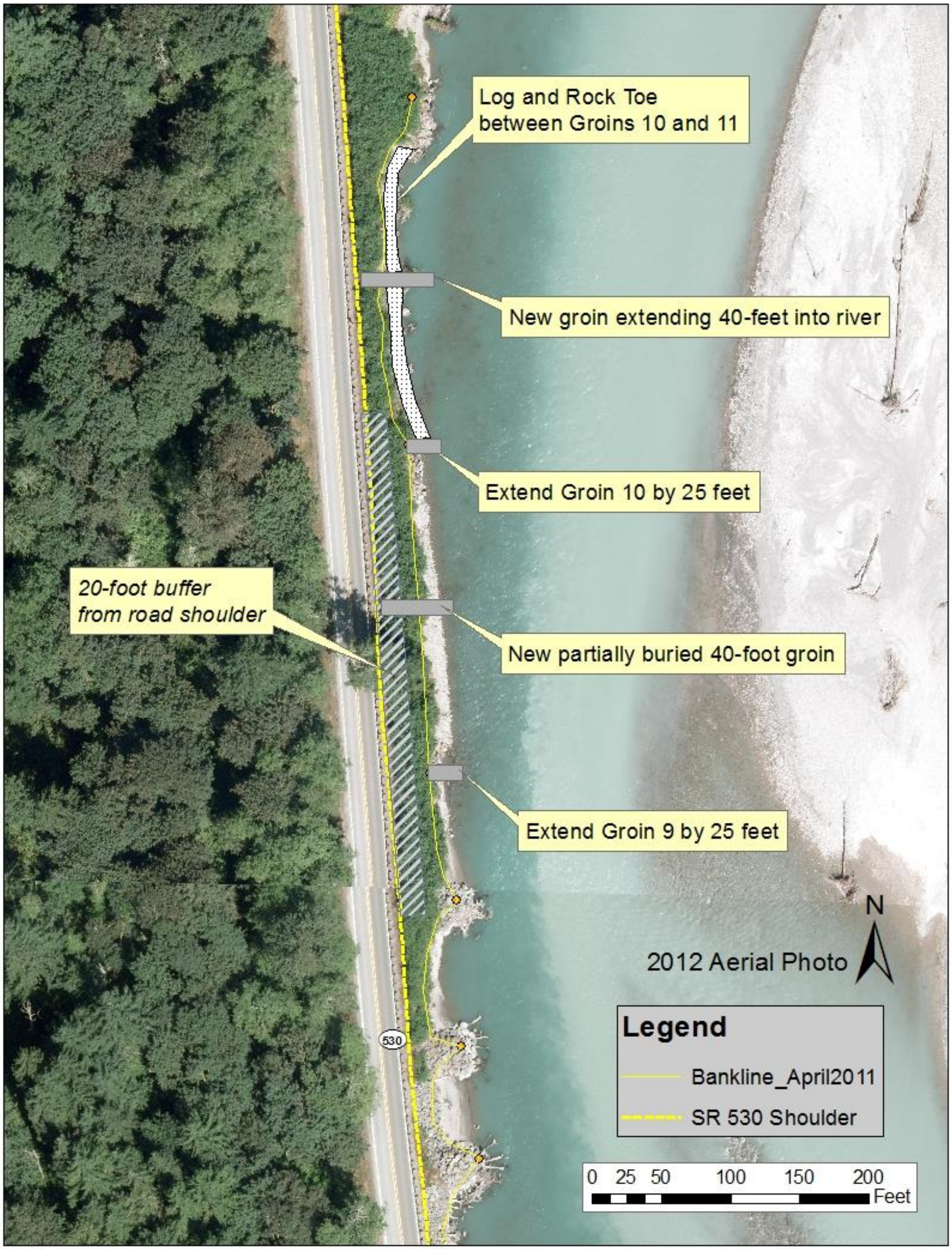

Figure 6. Locations of groin and bank protection Alternatives 1 and 2.

Similar modifications have been made to upstream Groins 3-8 (Figures 7 and 8). These groins are made primarily of large rock, with numerous rootwads buried in the rock matrix and projecting out from the edges of the groin to maximize roughness and wood recruitment. These structures create flow complexity, eddy resting habitat, and cover. Habitat impacts include loss of aquatic habitat under the footprints of the structures.

Figure 7. Groins and Roughened Log and Rock Toe upstream of Groin 9, 2009.

Figure 8. Groins and Roughened Log and Rock Toes after revegetation, August 2014.

Groins could also be configured as engineered log jams where the proportion of wood is higher (Alternative 1b in Table 2). Engineered log jams would provide more roughness, cover habitat, and opportunities for riparian planting on top of the jam. Construction would be more complex, with more excavation of the streambed and adjacent bank. These groins would involve more fill and a larger footprint on the aquatic bed than rock groins. Piles would also have to be driven to wedge and anchor the logs. Pile driving could have impacts to endangered salmon and other species, and permits might be more difficult to obtain.

Alternative 2 – Roughened Log and Rock Toe

Logs with rootwads would be placed along the toe of the failing bank, and anchored by burial with large rock (Figure 6). The rock would help stabilize the slumping bank, and the projecting rootwads would increase roughness and reduce velocities. The logs can be placed on top of the sloping sediment bar that occupies the toe of the bank. This is similar to treatments used between Groins 3 and 8 (Figures 7 and 8).

This treatment could either be applied by itself or as a complementary treatment between the Alternative 1 groins. If groins are not installed there is a higher likelihood of failure because velocities will be higher. Erosion has progressed to a point where armor of this type will be needed between Groins 10 and 11 regardless of whether additional groins are installed. If no additional groins are constructed toe armor would also be needed between Groins 9 and 10 where the existing riparian buffer is beginning to erode but is robust enough to be protected by the Alternative 1 groins without additional armor.

This treatment would protect the bank and provide more roughness and cover than the existing barren scarps, but would not provide as much flow complexity, eddy habitat, cover, and roughness as the groins. Placement would eliminate aquatic bed habitat under the rock toe.

Alternative 3 – Riparian Bench Reinforced with a Log Cribwall

A pile-anchored cribwall would be constructed along the bank between Groins 9 and 11, similar to an existing cribwall constructing downstream at MP 59.2 (Figures 9 and 10). The cribwall would be constructed by driving piles offshore and wedging rootwads and logs among the piles. Layers of logs would then be buried with rock, soil, and slash, and the top of structure would be planted with riparian trees and shrubs. This would provide a reinforced riparian buffer with high roughness and erosion resistance.

This structure would be constructed out into the river, thus reconstructing some of the riparian buffer that existed along the highway prior to the erosion problem. This would be particularly beneficial between Groins 10 and 11 where there is almost no remaining riparian buffer.

Geotechnical investigation would be needed to determine if piles could encounter bedrock or large boulders that would prevent construction. Bedrock is exposed in the bluff on the inland side of SR 530, but WSDOT borings did not encounter this material in holes drilled 27 feet below the top of bank.

Figure 9. Pile-anchored cribwall at SR 530 MP 59.2.

Construction would require extensive filling of existing aquatic bed habitat, and pile driving that could impact endangered salmon and other species. Rootwads projecting from the face of the structure would increase roughness and cover habitat along the entire length of the wall, but the linear structure would not provide as much large eddy habitat as the Alternative 1 groins.

Alternative 4 – Riparian Bench Reinforced with Dolo-anchored Log Clusters

This alternative would construct a reinforced riparian buffer between Groins 9 and 11, similar to Alternative 3. However, the bank in this case would be reinforced by placing interlocking clusters of logs anchored with concrete dolos. The area behind the log and dolo clusters would be filled with rock, slash, and soil, and planted with riparian trees and shrubs. This type of treatment was recently constructed on the Skagit River to protect SR 20 (Figure 11).

The benefits of this treatment would be similar to the Alternative 3 cribwall. It would avoid the risks and impacts of pile driving on endangered species, but would have a larger footprint on the aquatic bed. The concrete dolo elements of the structure may raise aesthetic concerns, and would likely involve more complex permitting negotiations because of less experience with this treatment by regulatory agencies.

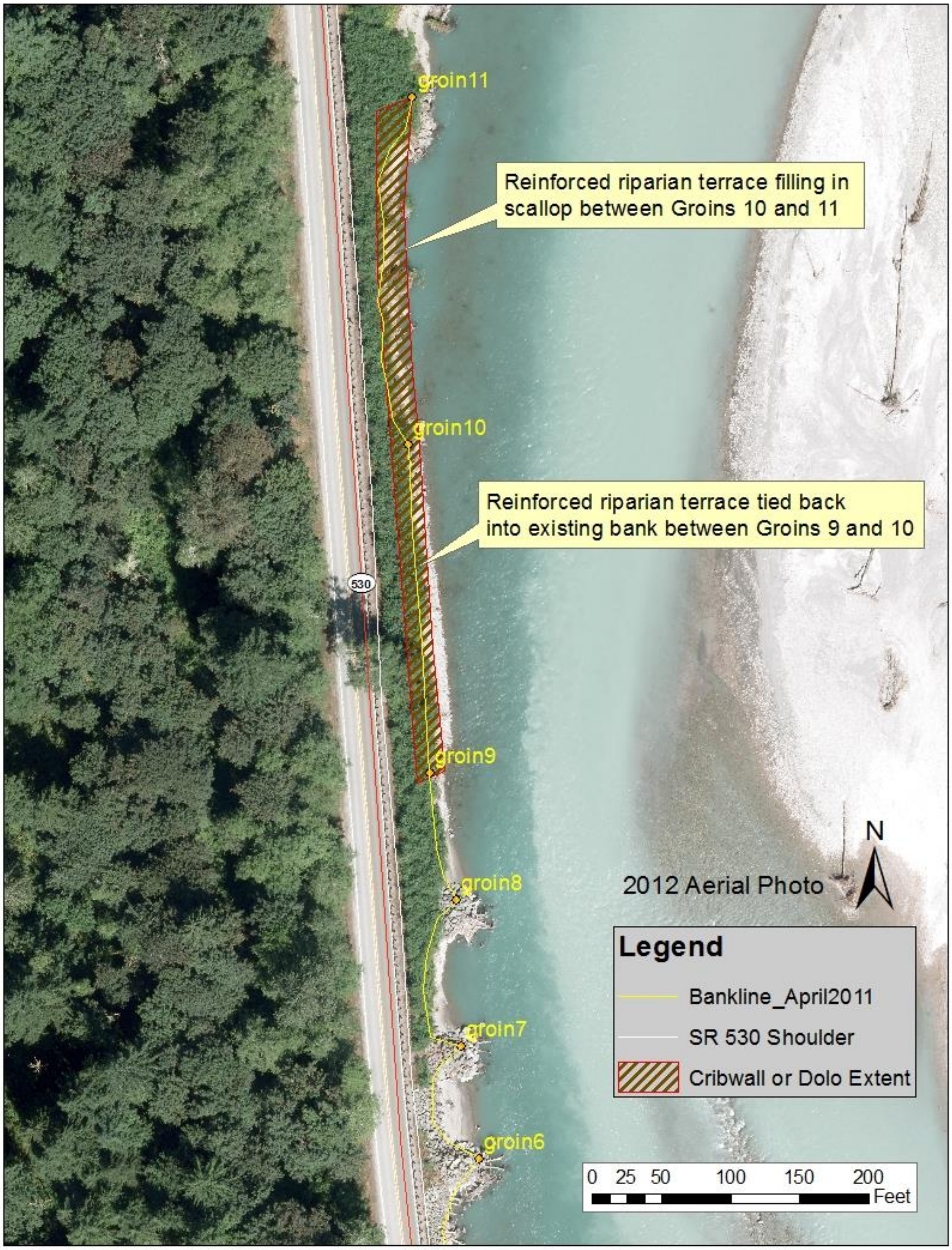

Figure 10. Extent of cribwall and dolo Alternatives 3 and 4.

Figure 11. Example of a dolo-reinforced log terrace protecting SR 20 on the Skagit River (Alternative 4).

Recommended Alternative

We recommend Alternative 1a (Rock and Log groins) because this would have the least impact on existing riparian and aquatic habitat, and would be consistent with upstream bank treatments. Groins have successfully protected other segments of the site when they are properly spaced. The groins should be constructed of toe logs ballasted with rock to avoid impacts of pile driving and to minimize excavation. About 200 feet of bank between the footprints of Groins 10 and 11 should also be reinforced with a log and rock toe (Alternative 2) because it has failed close to the point where erosion could undermine the road prism.

Alternatives 3 and 4 (riparian benches) would involve extensive disturbance of riparian areas between Groins 9 and 10, and would have a much larger footprint on aquatic bed habitat. These alternatives would also be much more expensive, and Alternative 3 would involve pile driving impacts to endangered salmon. Alternative 2 (roughened toe) has less habitat benefits if installed without groins and does not provide as much velocity reduction and bank protection as does Alternative 1.

Interim Maintenance Plan

WSDOT should continue to monitor the condition of the bank and existing protection structures until a more permanent repair can be funded and constructed, particularly in the segment between Groins 10 and 11 where the unarmored bank is retreating most rapidly. Emergency repairs will be needed if the erosion begins to undermine the road prism. These repairs will most likely consist of rock armor similar to previous repairs used on site. Where practicable the toe of the repair should include oversized rock to roughen the face and reduce velocities. Large woody material should also be incorporated into the toe of the repair where practicable, depending on flow conditions and availability of woody material at the time of the emergency repair.

References

U.S. Department of Agriculture, 1981. Soil Survey of Skagit County Area, Washington.

U.S. Geological Survey, 2007. Peakfq Version 5.2, Annual Peak Flow Analysis using Bulletin 17-B Guidelines.

U.S. Geological Survey, 2014. National Water Information System, Peak Flows for Washington. http://nwis.waterdata.usgs.gov/wa/nwis/peak/?site_no=12189500&agency_cd=USGS, accessed September 2014.

Washington State Conservation Commission, 2003. Salmon and Steelhead Habitat Limiting Factors, Water Resource Inventory Areas 3 and 4, The Skagit and Samish Basins.

Washington State Department of Fish and Wildlife. 2003. Integrated Streambank Protection Guidelines. Aquatic Habitat Guidelines Program. http://www.wdfw.wa.gov/hab/ahg/ispgdoc.htm.

Washington State Department of Transportation, 2007. Emergency Site and Reach Assessment, SR 530, Sauk / Suiattle Confluence MP 55.5, Headquarters Environmental Services Office.

Washington State Department of Transportation, 2009. Geomorphic Monitoring Report, SR 530 Sauk-Suiattle Confluence Emergency Bank Stabilization, Environmental Services Office Hydrology Program.

Washington State Department of Transportation, 2010. Geomorphic Monitoring Report, SR 530 Sauk-Suiattle Confluence Emergency Bank Stabilization, Environmental Services Office Hydrology Program.

Washington State Department of Transportation, 2011. Geomorphic Monitoring Report and Adaptive Management Repair Recommendations, SR 530 Sauk-Suiattle Confluence Emergency Bank Stabilization, Environmental Services Office Hydrology Program.